Modernizing Systems and Software
- How Evolving Trends in Future Trends in Systems and Software Technology Bode Well for Advancing the Precision of Technology

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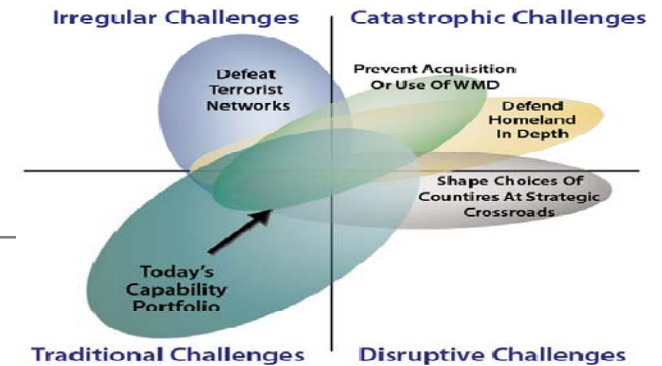**Software Engineering Institute** | **Carnegie Mellon**

Overview

- **Transformational Trends**
  - Development
  - Acquisition
  - Human Element
  - Risk Management
  - Communications

- **Ten Future Trends**

- **Wrap-up**

Development: Need for Space, Air, Ground, Water, Underwater Software-Intensive Systems that are Interconnected

- Several million SLOC programs; "Hybrid" systems combining legacy re-use, COTS, new development
- Multi-contractor teams using different processes; dispersed engineering, development & operational locations
- New technologies create opportunities/challenges; products change/evolve, corporations mutate
- Business/operational needs change - often faster than full system capability can be implemented
- Skillset Shortfalls; Cost and schedule constraints
- Demands for increased integration, interoperability, system of system capabilities
- Enterprise perspectives/requirements; sustainment concerns
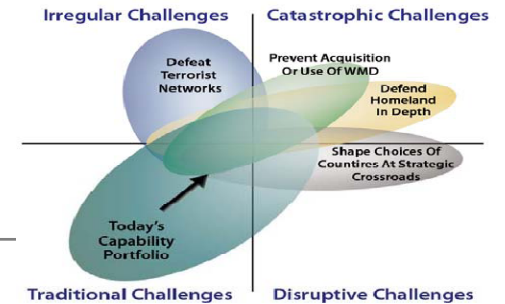
Development Complexity of Software-Intensive Systems is Increasing
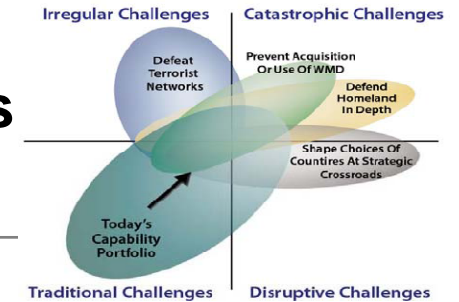
Software Engineering Trends That Impact Systems Engineering

Traditional	Future
• Standalone systems	• Everything connected-maybe
• Mostly source code	• Mostly COTS components
• Requirements-driven	• Requirements are emergent
• Control over evolution	• No control over COTS evolution
• Focus on software	• Focus on systems and software
• Stable requirements	• Rapid change
• Premium on cost	• Premium on value, speed, quality
• Staffing workable	• Scarcity of critical talent

Emerging Dynamics of Bringing Systems and Software Engineering in Continued Partnership

The Acceleration of Innovation in the 21st Century:
- Impacting Both Defense and Society

Linear vs. Exponential Growth: — Linear Plot

- Exponential trend
- Linear trend

The Amount of New Technological Innovation is Doubling Every Two Years

- Requires More Upfront SE/SW Engineering to Leverage Trends

Knee of Curve →

Ray Kurzweil, et. al

Technology Capability — Time
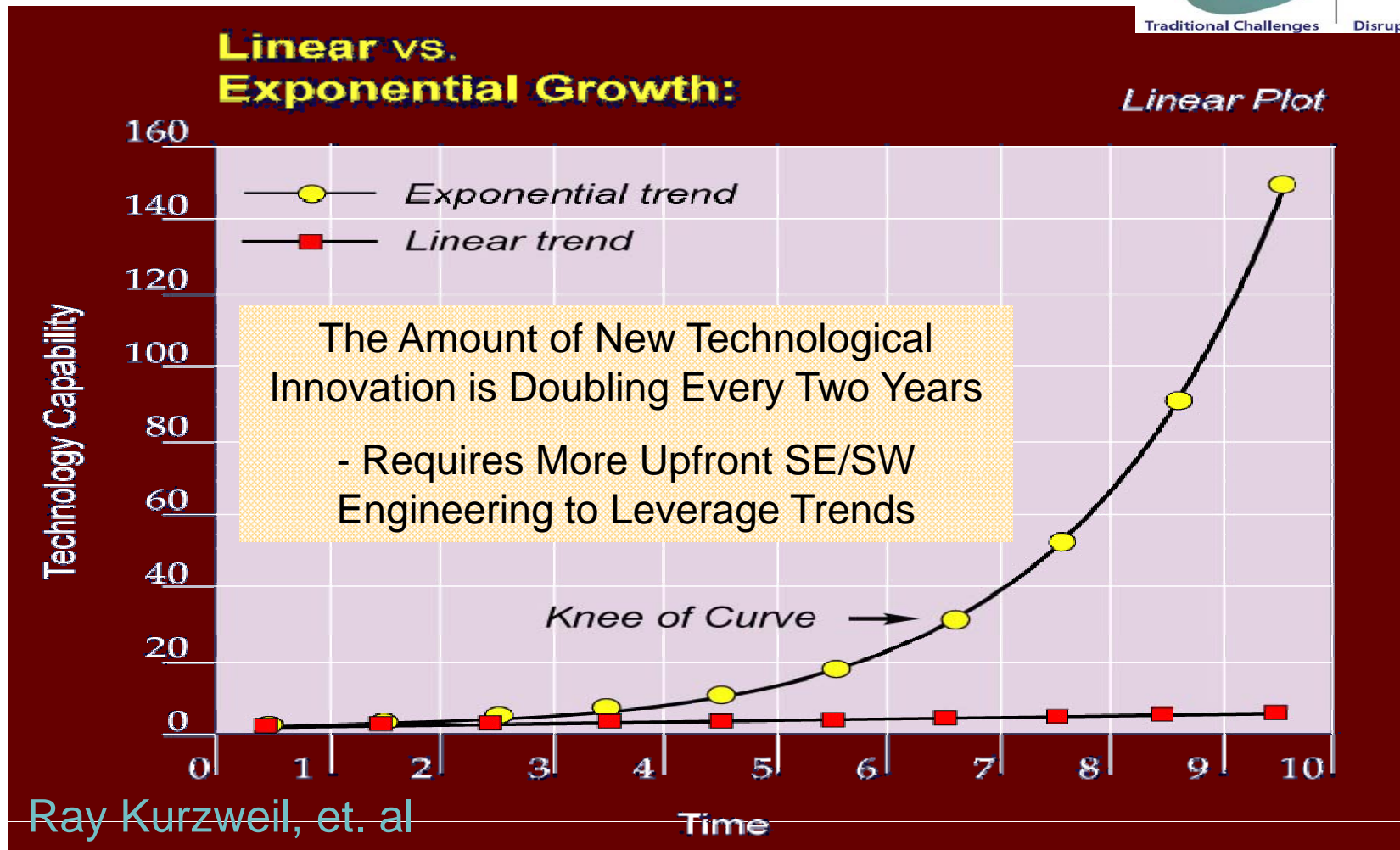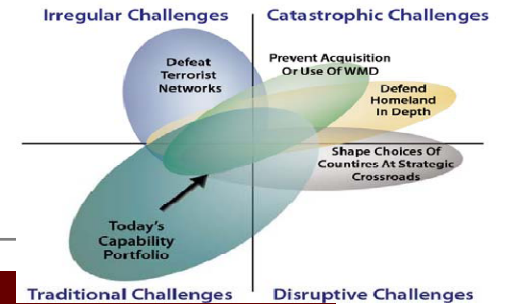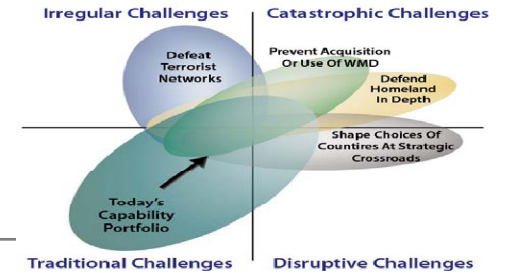
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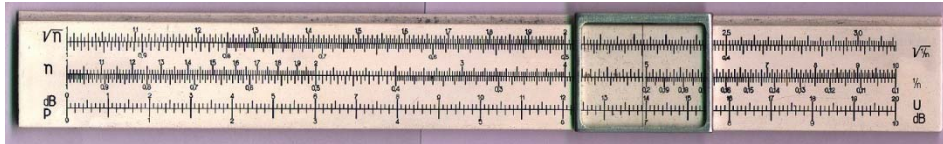# Augustine's Law: Growth of Software - Order of Magnitude Every 10 Years

In The Beginning

1960's	1970's	1980's	1990's	2000+
F-4A 1000 LOC	F-15A 50,000 LOC	F-16C 300K LOC	F-22 1.7M LOC	F-35 >6M LOC

Trend & Implications: Augustine's Law Will Hold
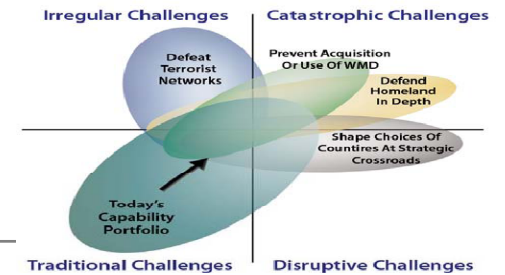
2080?

F-50 - 4.7B Lines of Code

Need for increased functionality will be a forcing function to bring the fields of software and systems engineering closer together

Moore's Law: The Number of Transistors That Can Placed on an Integrated Circuit is Doubling Approximately Every Two Years
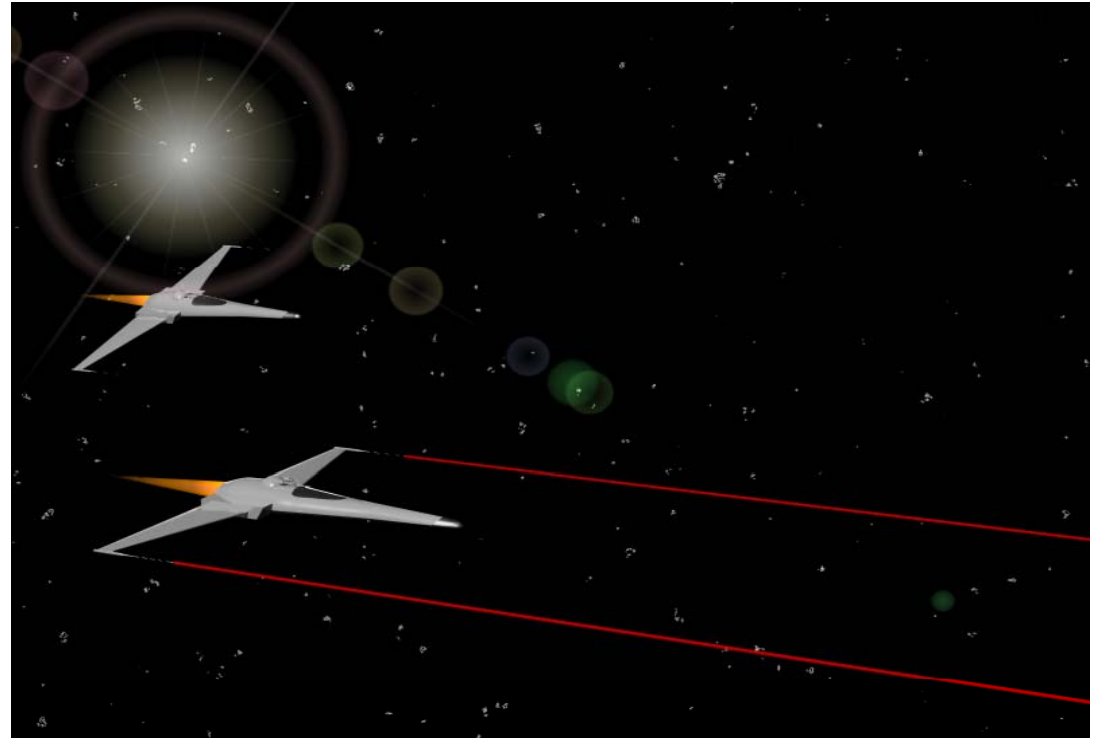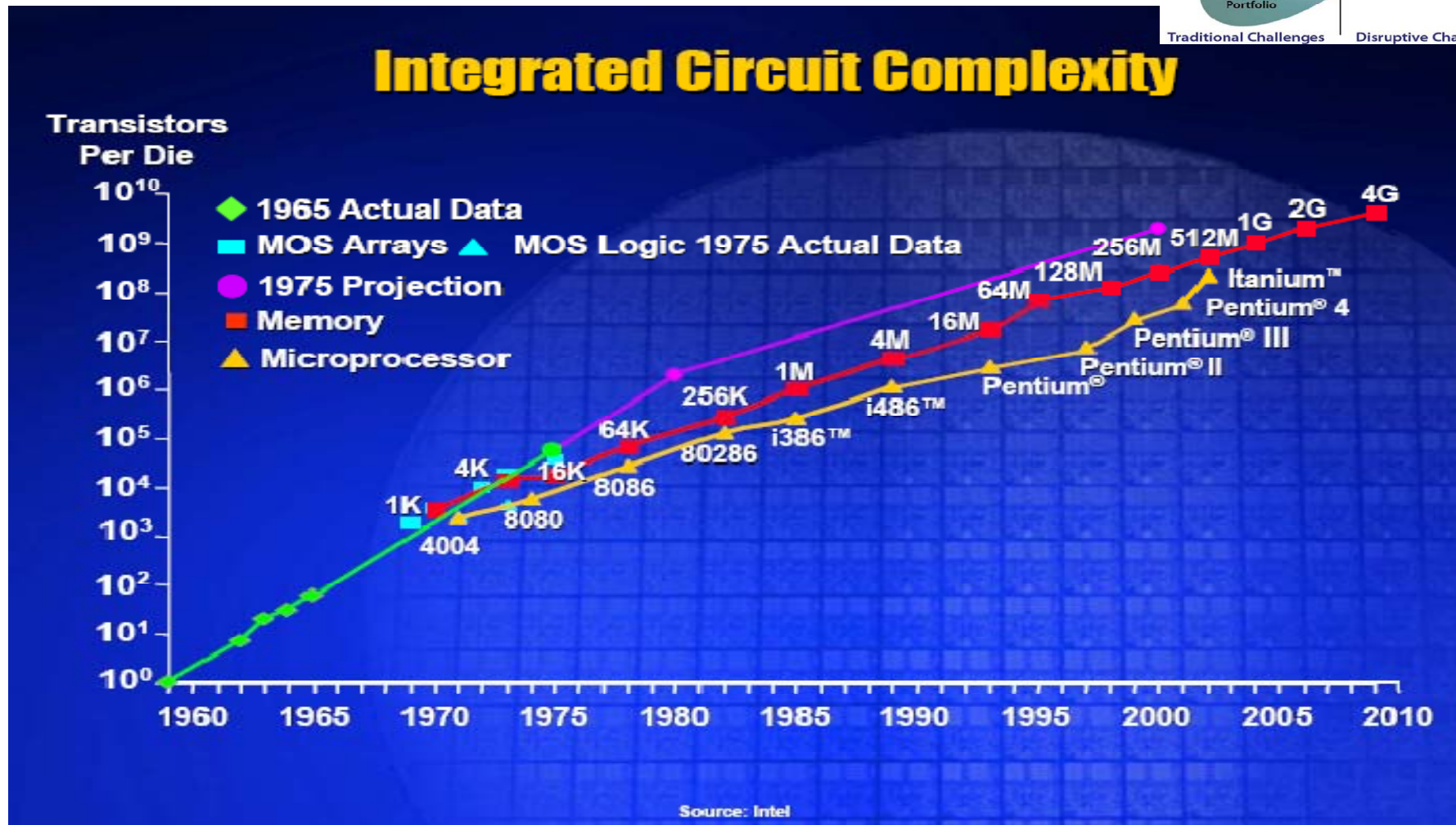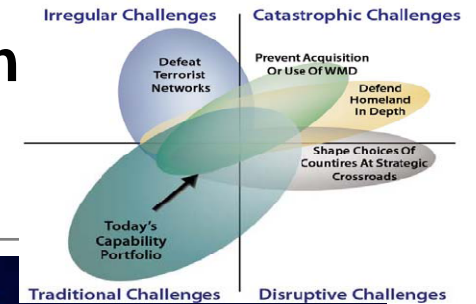
Increased Technological Rate of Adoption
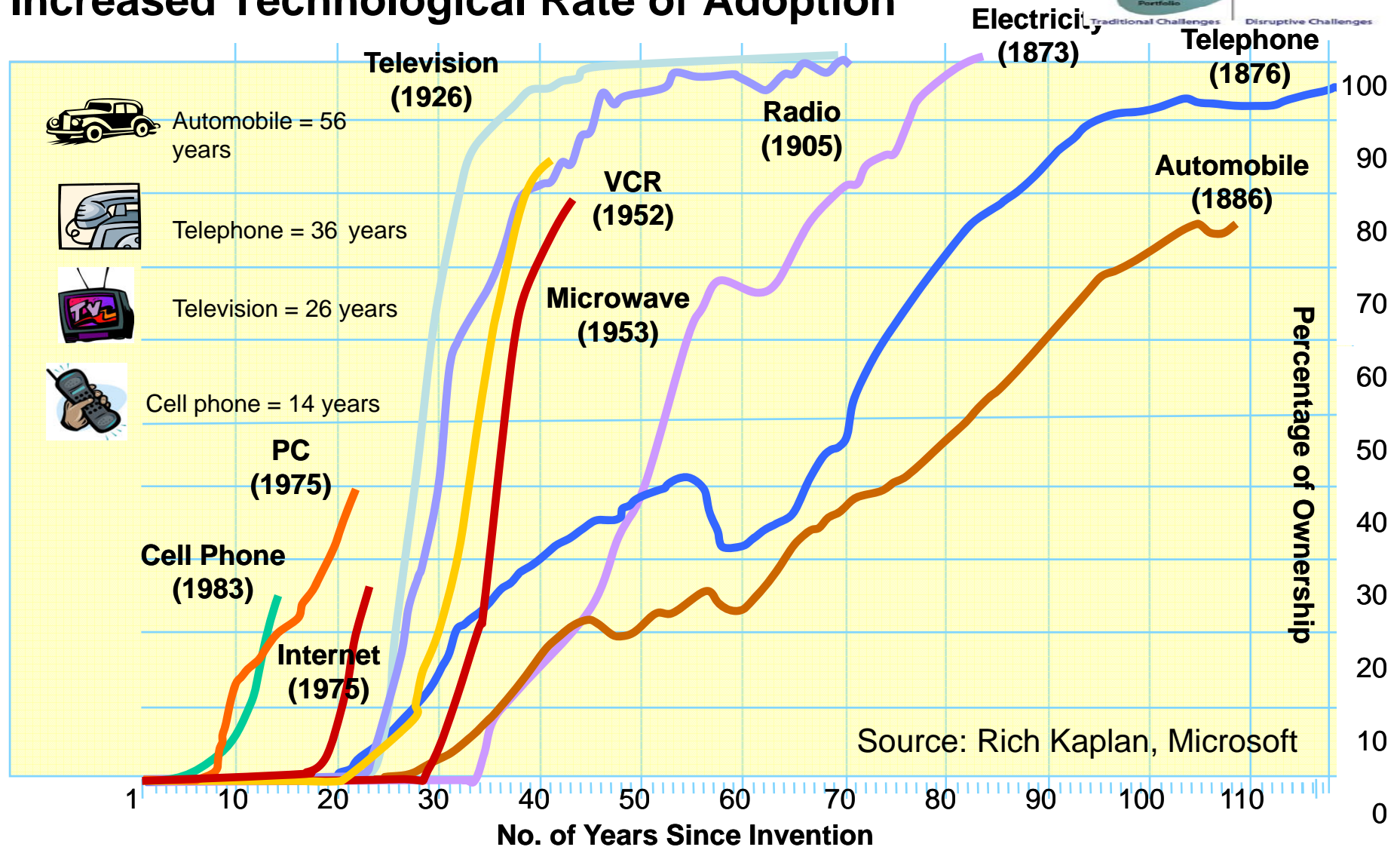
Automobile = 56 years

Telephone = 36 years

Television = 26 years

Cell phone = 14 years

Television (1926)

Electricity (1873)

Telephone (1876)

Radio (1905)

VCR (1952)

Automobile (1886)

Microwave (1953)

PC (1975)

Cell Phone (1983)

Internet (1975)

Source: Rich Kaplan, Microsoft

Percentage of Ownership

No. of Years Since Invention

Relationship Between Complexity and Acquisition Success Improving and More Improvements are on the Way

Software is Growing in Complexity

- 80% of some weapon system functionality is dependent upon software
- Consequences of software failure can be catastrophic

Software Acquisition is Difficult

- 46% are over-budget (by an average of 47%) or late (by an average of 72%)
- "Successful projects" have 68% of specified features

Software is Pervasive

- IT Systems, C4ISR, Weapons, etc

On-going Changes to the Acquisition Process Targeted at Correcting this Issue
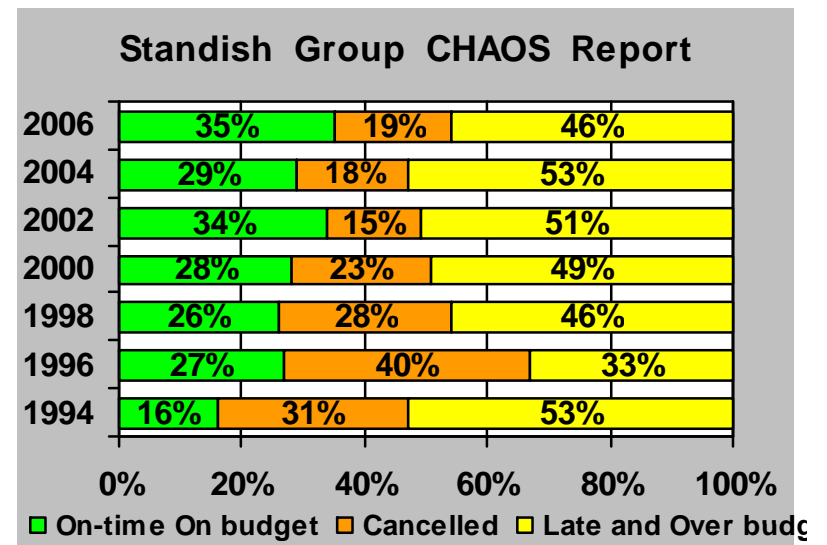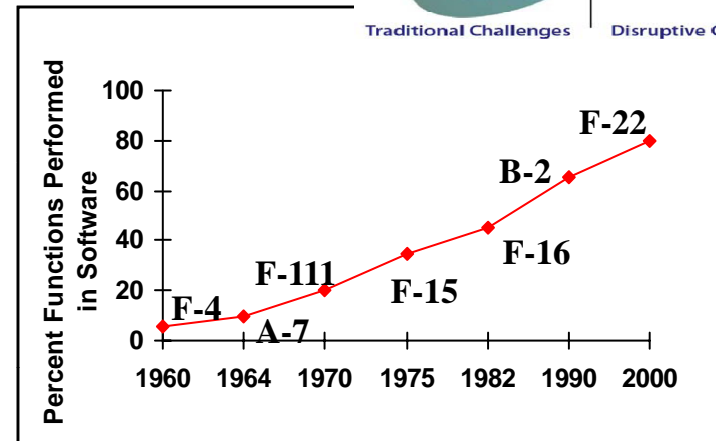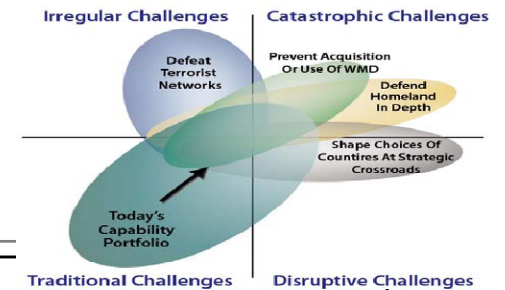
Standish Group CHAOS Report

Year	On-time On budget	Cancelled	Late and Over budget
2006	35%	19%	46%
2004	29%	18%	53%
2002	34%	15%	51%
2000	28%	23%	49%
1998	26%	28%	46%
1996	27%	40%	33%
1994	16%	31%	53%

☐ On-time On budget ☐ Cancelled ☐ Late and Over budget

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Acquisition: Life of a Program Manager in a System of Systems and/or Net-Centric Operation.
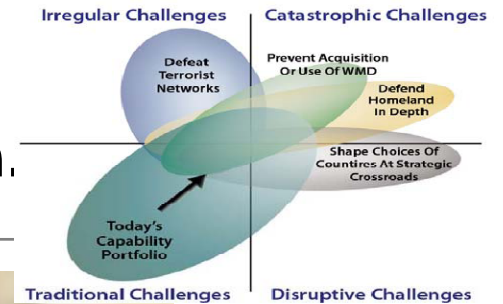
Acquisition: Effectively Managing Risk
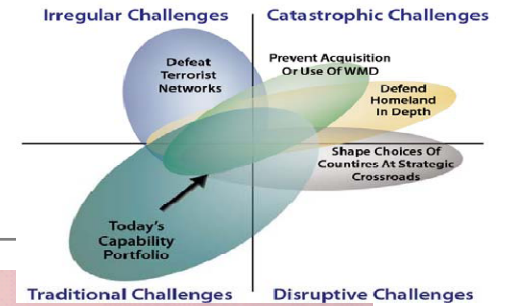
A Key Challenge is How to Obtain a Better Alignment of Risk Among the Relevant Stakeholders

Acquisition Challenges: Some Drivers That Increase the Risk of Acquiring Software-Intensive
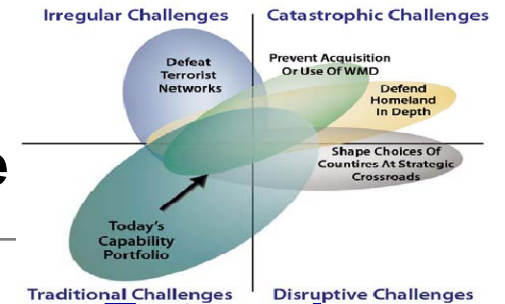
Platform   ⟶   Enterprise

Customer Emphasis

Requirements   ⟶   Objectives/ Capabilities

Acquisition Model

Dominant Prime   ⟶   Strategic Teaming

Program Execution

"Boxes"   ⟶   "Layers & Stacks"

Integration Challenge

Proprietary   ⟶   Plug & Play

Architectures and Standards

Need Exists to Address Both Sides, and Do So with Compressed Delivery Schedules via Improvements in Systems/Software Engineering

Acquisition Performance – Flexible Boundary-Crossing Acquisition Structure
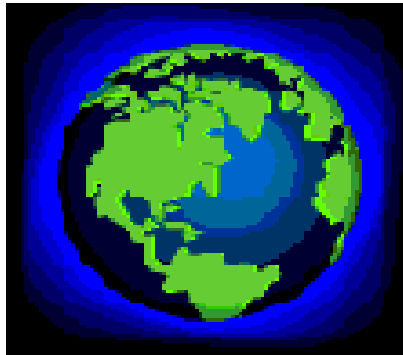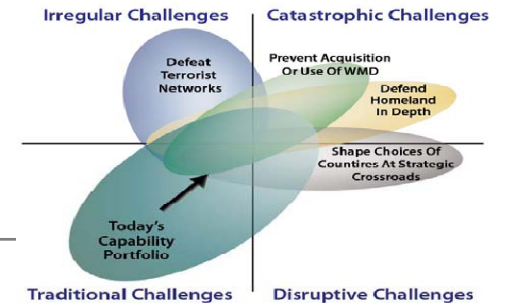
2005 study confirmed*:

• In advanced knowledge-based organizations, management's desire for the flow of knowledge is greater than the desire to control boundaries

• Unlike the matrix organization, there is less impact on the dynamics of formal power and control

• Important to measure the system in terms of user performance

* Using Communities of Practice to Drive Organizational Performance and Innovation, 2005, APQ study

"**Acquisition**" ← Advanced Knowledge-Based Organizations (Big A)

"acquisition"
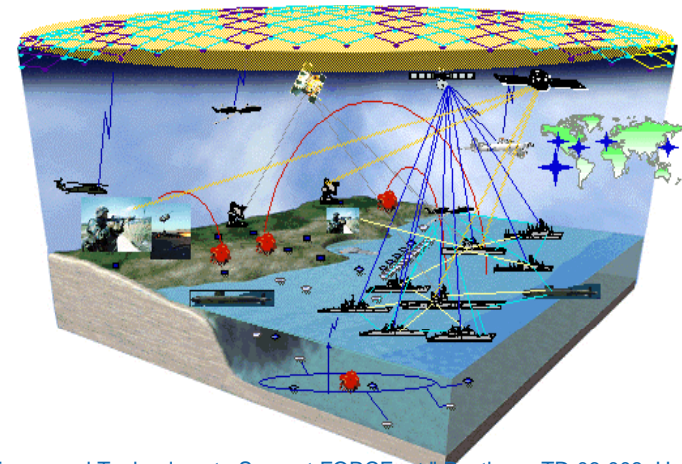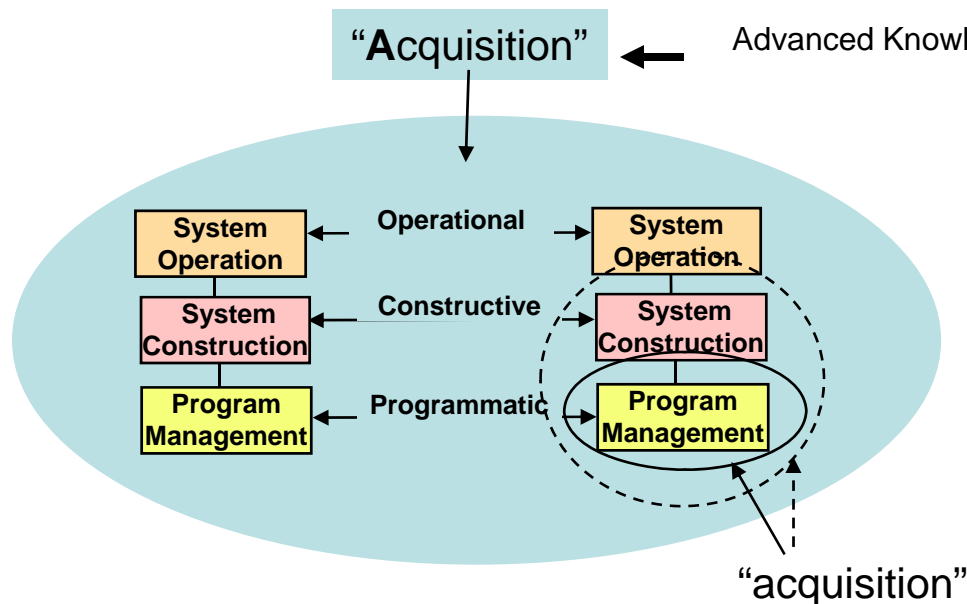
From "Science and Technology to Support FORCEnet," Raytheon TD-06-008. Used by permission.

Ref: Jim Smith, (703) 908-8221, **jds@sei.cmu.edu**

Human Element

The ability of organizations to compete will increasing depend on the innovation of the human element

Society Drivers: Bimodal Demographics (Space Industry)

Reconstituting This Group

Graduate School Shortfall

54% of the S&T W Over 45 and 33% will be retirement eligible in 5 years

Irregular Challenges   Catastrophic Challenges
Defeat Terrorist Networks
Prevent Acquisition Or Use Of WMD
Defend Homeland In Depth
Shape Choices Of Countires At Strategic Crossroads
Today's Capability Portfolio
Traditional Challenges   Disruptive Challenges

Area of Concern

Area of Concern

- 18-24: 1%
- 25-29: 6%
- 30-34: 19%
- 35-39: 11%
- 40-44: 9%
- 45-49: 21%
- 50-54: 14%
- 55-59: 9%
- >60: 10%

Average Space Industry S&E Workforce Age Distribution

Trend: Industry/Gov't Will Increasingly Focus on Attracting, Training and Retaining Systems Engineering Talent

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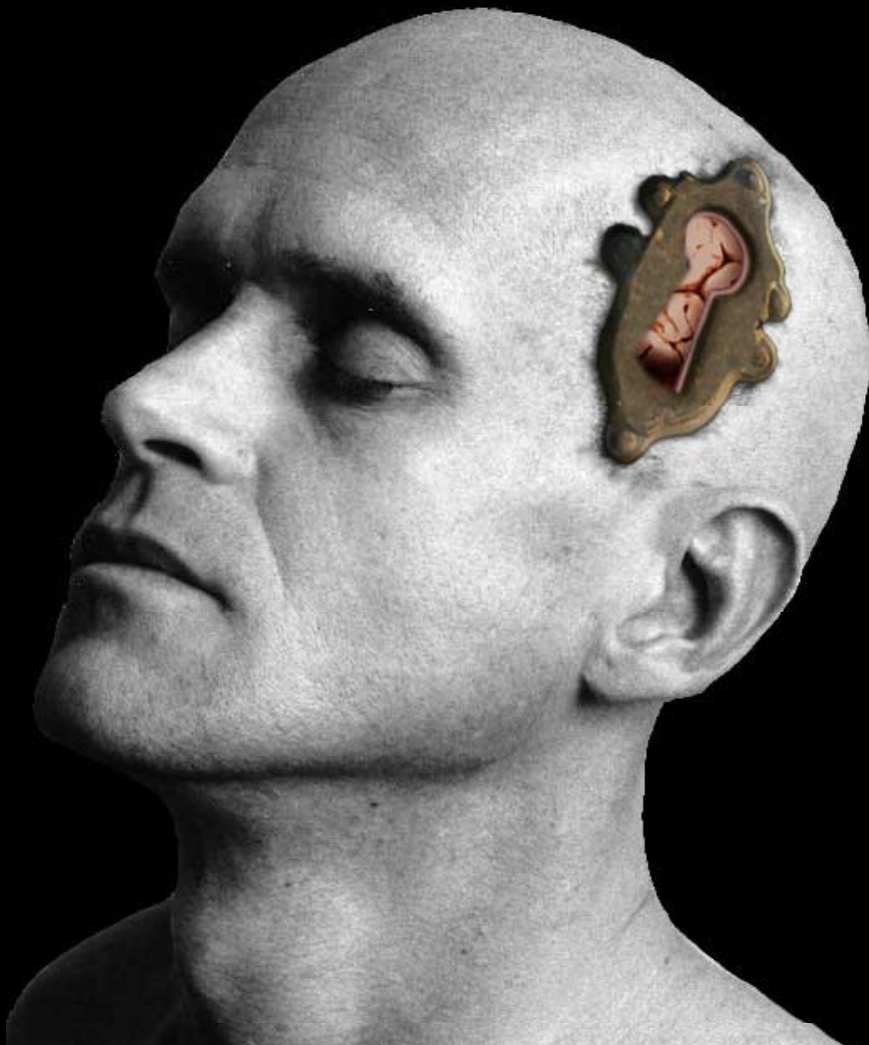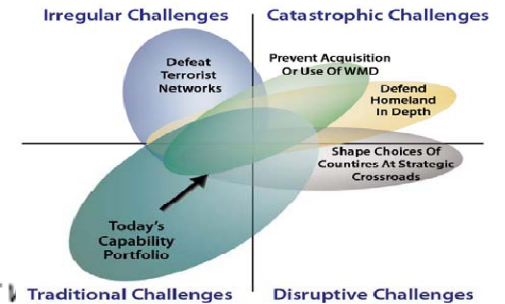
Source: Lockheed Martin (0004305-001: AIAA SE Workforce Data. Frank Cappuccio VP & GM Skunk Works)

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Objective is for Software and Systems Engineering to Become More Integrated Versus Separated

System Analysis				System Testing

Systems Engineering (SE)

SW Systems Engineering

Systems Engr. — System Design — System Integrated Testing — Systems Engr.

SW Systems Engr. — Software (SW) Requirements Analysis — SW System Testing — SW Systems Engr.

Architectural SW Design — SW Integration Testing

SW Engineering — Detailed SW Design — SW Subsystem Testing — SW Engineering

Code and Unit Test

OSD Initiative: Integrated Software and Systems Engineering Curriculum

Human Element in the Work-Space Environment

Source: Doug Phair; Technology Evangelist;
dphair@mitre.org; February 2008

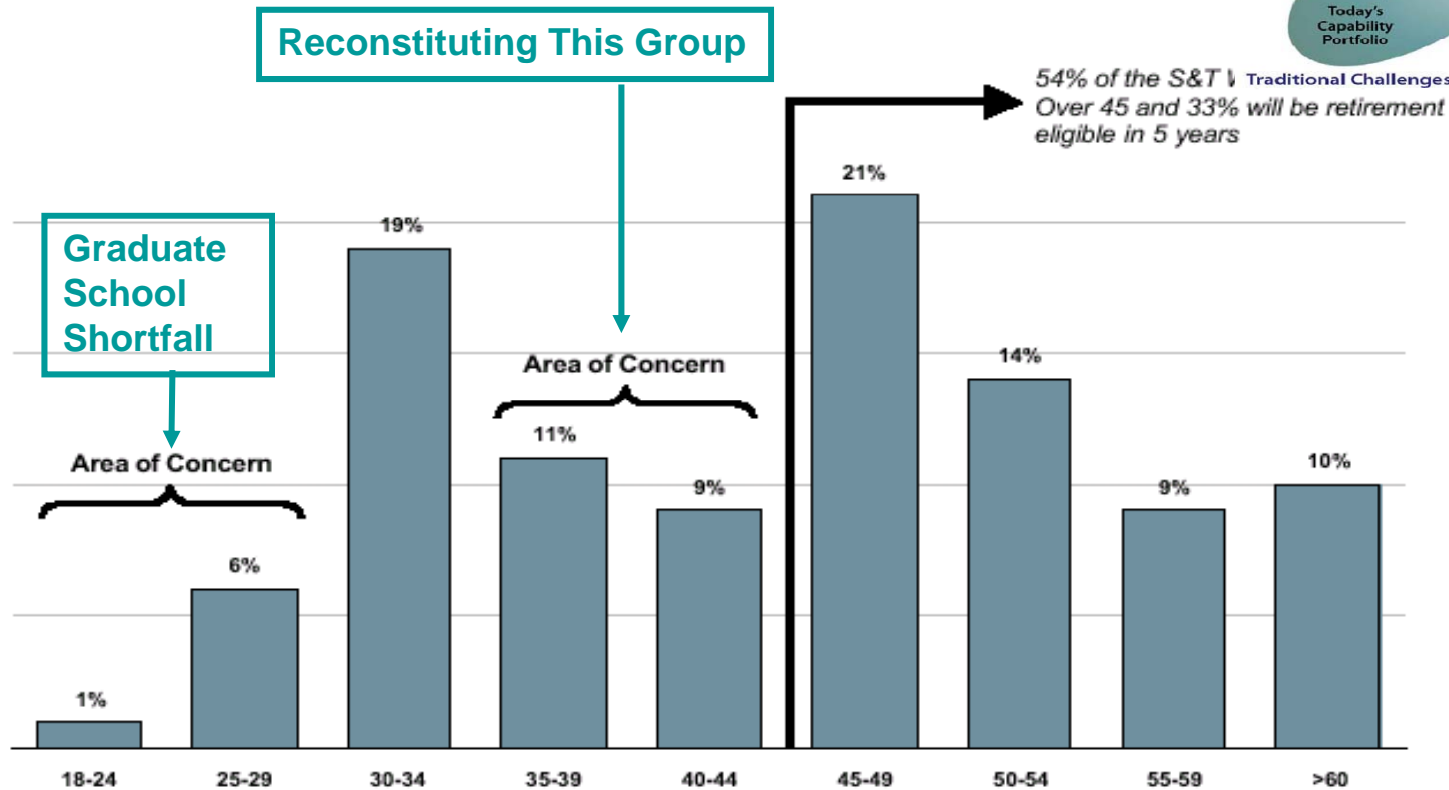**Software Engineering Institute** | **Carnegie Mellon**

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Managing Multiple Generations: Cultural Differences
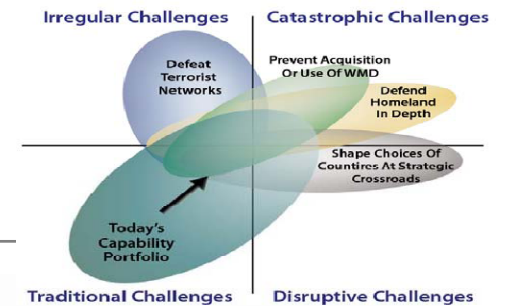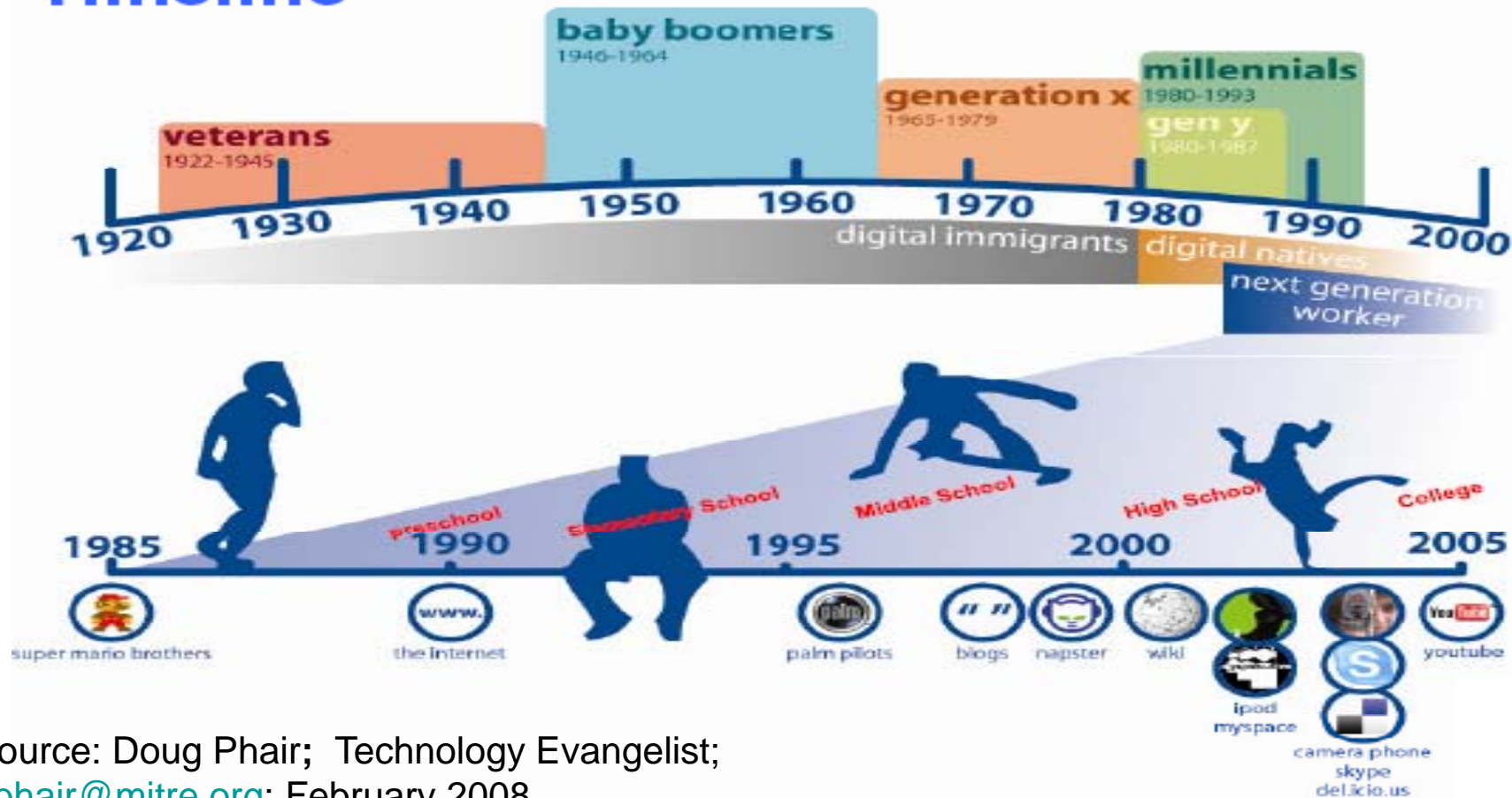

Traditionalist	Baby-Boomer	Generation X	Generation Y
1928-1945	1946 - 1964	1965 - 1980	1980 - 2000

Traditionalist	Baby-Boomer	Generation X	Generation Y
▪Hard worker	▪Workaholic	▪Technically savvy	▪Prefer informality
▪Respects authority	▪Questions authority	▪Prefer informality	▪Learn quickly
▪Work is an obligation	▪Works efficiently	▪Learns quickly	▪Embrace diversity
▪Communicates formally & in person	▪Competitive	▪Communicates directly & immediately	▪Requires supervision
▪Organizational loyalty	▪No news is good news	▪Wants structure & direction	▪Indirect communication: email & texting
▪Work & family don't mix	▪Work to live, little balance between work/family	▪Seek work/life balance	▪Seek "demand" work/life balance

Trends Affecting the Workforce
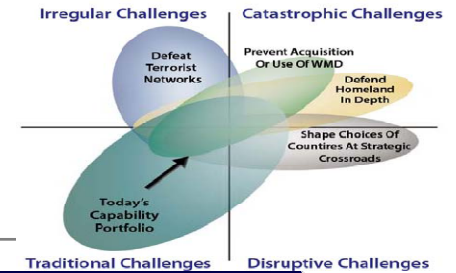
From	To
Doers differ from thinkers →	Doers must be thinkers
Assets are things →	Assets are people
Labor is an expense →	People are an investment
Lifetime employment →	Lifetime employability
Top down control →	Decentralized decisions
Localized work →	Networked problems solved
Measure for results →	Measure for improvements

Pfeffer (1994)

Communication: Increased Capabilities in the Digital Spectrum Enables Improvements in Communication and Collaboration

ULTRABAND

Virtual Presence

B R O A D B A N D

M O D E M S

Kilobit/Sec.	Megabit/Sec.	Gigabit/Sec.	Terabit/Sec.
$1,000 - 10^3$	$1,000,000 - 10^6$	$1,000,000,000 - 10^9$	$1,000,000,000,000 - 10^{12}$

Rule #4: The best companies are the best collaborators*

* Friedman, Thomas L. "*The World Is Flat*", Farrar, Straus and Giroux, 2005

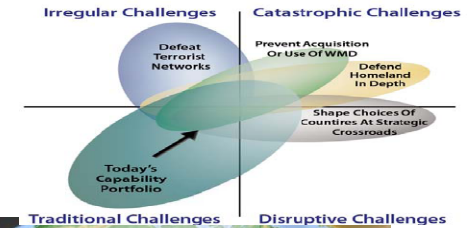**Software Engineering Institute** | **Carnegie Mellon**

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Communications Among Systems –Fostering a Growing Interdependence and Integration
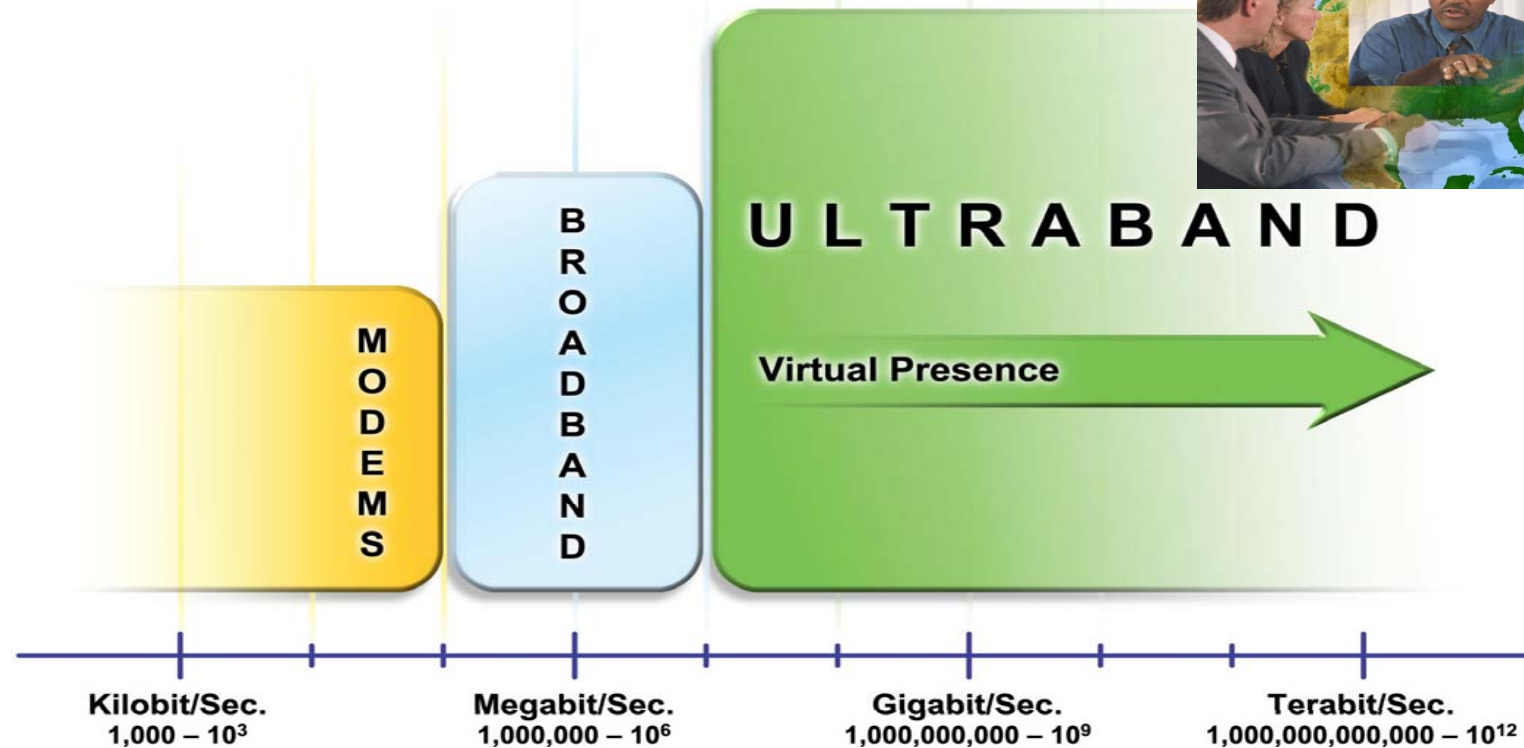
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Implication: Improvements in Collaboration Mechanisms Are Enablers for System and Software Engineering Success

Problem Identification: Ultra-Large-Scale (ULS) Systems – The Software Challenge of the Future

Gather leading experts to study:

- Characteristics of ULS systems

- Challenges and breakthroughs required

- Promising research and approaches

Intended outcomes:

- ULS Systems Research Agenda

- Program proposal

- Collaborative research network

ULS systems study

About the Effort
Funded by the Army (ASA ALT)
Staffing: 9 member SEI team; 13 member expert panel

Study lead – Linda Northrop, SEI

Systems and Software Engineering: Ten Trends

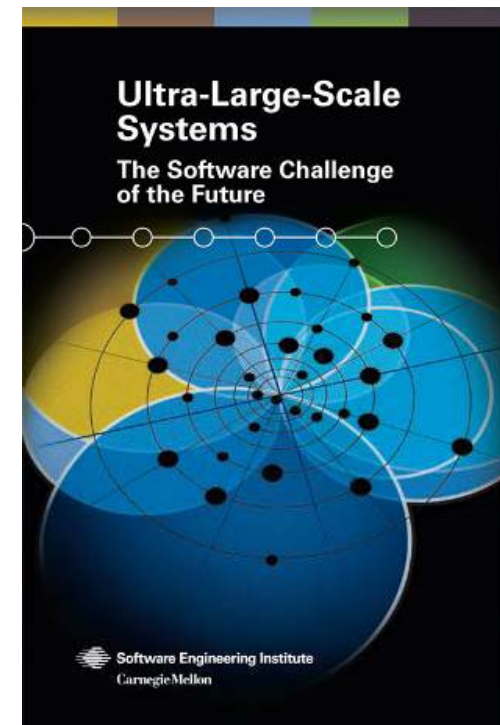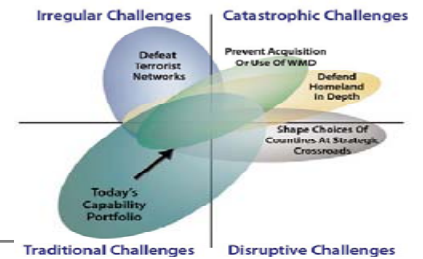- *Greater demands on systems and software engineers will stimulate growth in the field – nationally and internationally*

- *Industry/Gov't will increasingly focus on attracting, training and retaining systems and software engineering talent – short and long run – with emphasis on providing a Generation Y work environment*

- *Increased reliance on systems and software engineering processes and technologies to effectively manage the acquisition/"green" space*

- *The laws of Augustine's and Moore will continue to hold and will continue to be a forcing function to bring the fields of software and systems engineering closer together*

- *Improvements in program risk-reduction collaboration mechanisms will be significant enablers for increases in systems and software engineering communication and "decision velocity"*

Systems and Software Engineering: Ten Trends

- *Increased need for a large number of complex systems and systems of systems will lead to investments in research and technology*

- *Systems and software engineers will continually find way to innovative to reduce complexity*

  - *Increased importance of modeling and simulation*

  - *Increased reliance on architectures (top-down and bottoms-up)*

  - *Increased design for continuous evolution and deployment at all levels will occur*

    - *Understanding users and their context will evolve, e.g. leaner system and software engineering process assets on projects*

- *Increased customer requests for system and software engineering support earlier in life cycle*

- *Shift of systems and software engineering focus from the platform to systems of systems*

- *Process improvement will continue to be important*

Questions?

THE
KNOWN WORLD
*Beyond here there
be Dragons*

Recommended Readings

Buckman, Robert H. *Building a Knowledge-Driven Organization.* McGraw-Hill, New York, NY, 2004.

Chao, Pierre A. "Alternative Futures for the Defense Industry." Center for Strategic & International Studies, Chantilly, VA, April 2005.

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Drucker, Peter. *Managing in the Next Society.* Truman Talley Books, New York, NY, 2003.

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Mahnken, Thomas, Deputy Assistant of Defense for Policy Planning, OSD, Visions of Transformation 2005, Feb 2007

Malone, Thomas. *The Future of Work: How the New Order of Business Will Shape Your Organization, Your Management Style and Your Life.* Harvard Business School Publishing, Boston, MA, 2004. See http://ccs.mit.edu/futureofwork/

Nidiffer, Kenneth E. and Doland, Diana "Evolving Distributed Project Management", special issue IEEE Software, Sept/Oct 2005

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Wladawsky-Berger, Irving. "The Future of IT in an On-Demand World." IBM Server Group, Keynote address at OSBC 2005. Archived at http://www.itconversations.com/shows/detail495.html

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